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(12) United States Patent
Snow

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(45) Date of Patent: May 15, 2007

(54) **HEART STABILIZER**

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(73) Assignee: **Intuitive Surgical, Inc.**, Sunnyvale, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 254 days.

(21) Appl. No.: **10/892,386**

(22) Filed: **Jul. 14, 2004**

(65) **Prior Publication Data**

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Related U.S. Application Data

(63) Continuation of application No. 09/870,331, filed on May 29, 2001, now Pat. No. 6,817,972, which is a continuation-in-part of application No. 09/411,442, filed on Oct. 1, 1999, now Pat. No. 6,936,001.

(51) **Int. Cl.**
A61F 13/00 (2006.01)
A61B 1/32 (2006.01)

(52) **U.S. Cl.** **600/37**; 600/215; 600/222

(58) **Field of Classification Search** 600/37, 600/201, 210, 215, 222, 227, 228, 235; 128/897–898
See application file for complete search history.

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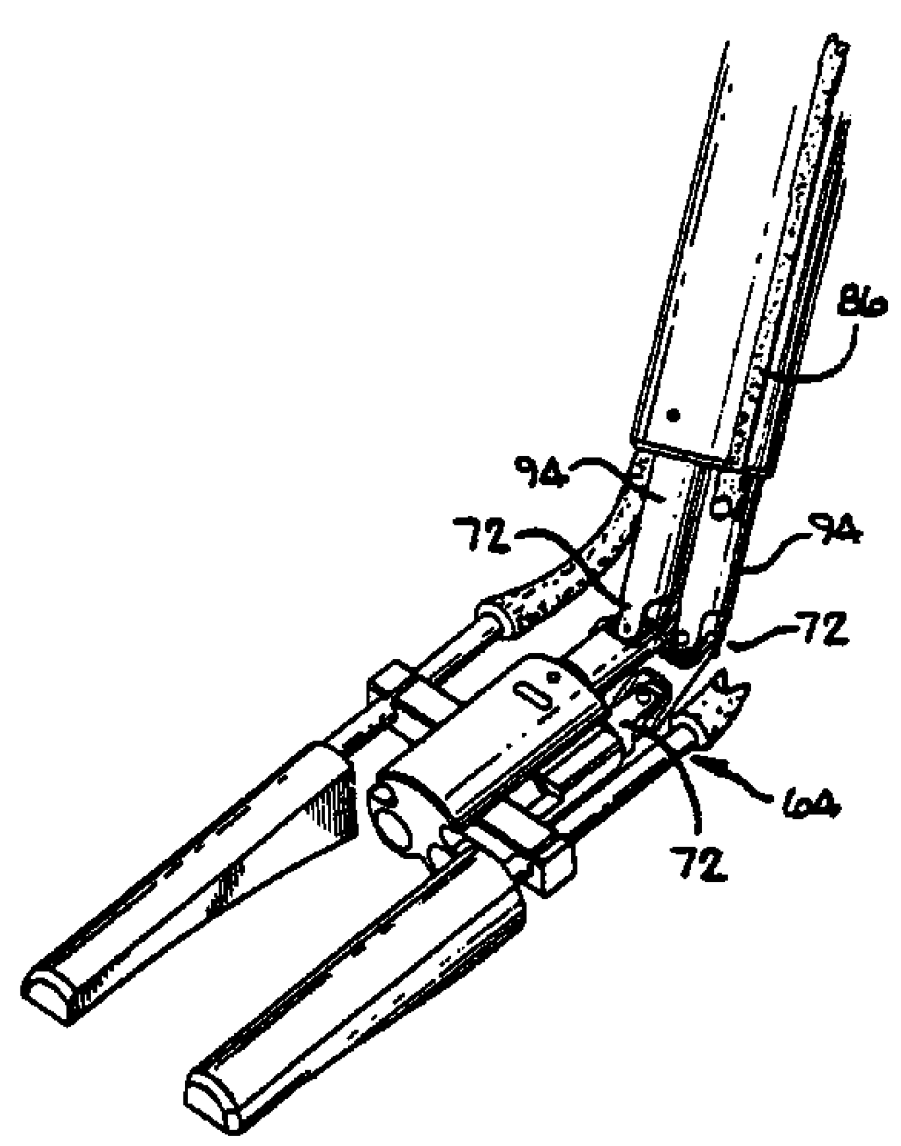
(Continued)

Primary Examiner—John P. Lacyk

(57) **ABSTRACT**

A heart stabilizer that may include a wrist which couples an end effector to a first linkage. The end effector and wrist may be inserted through an incision in the chest of a patient to assist in performing a minimally invasive coronary procedure. The wrist provides dexterity so that the end effector can be placed on the heart to stabilize the same. The end effector may include a pair of paddles that are moved between open and closed positions by a pair of manually actuated levers. The paddles may have cleats that allow sutures to be attached to the stabilizer during a minimally invasive procedure.

9 Claims, 11 Drawing Sheets



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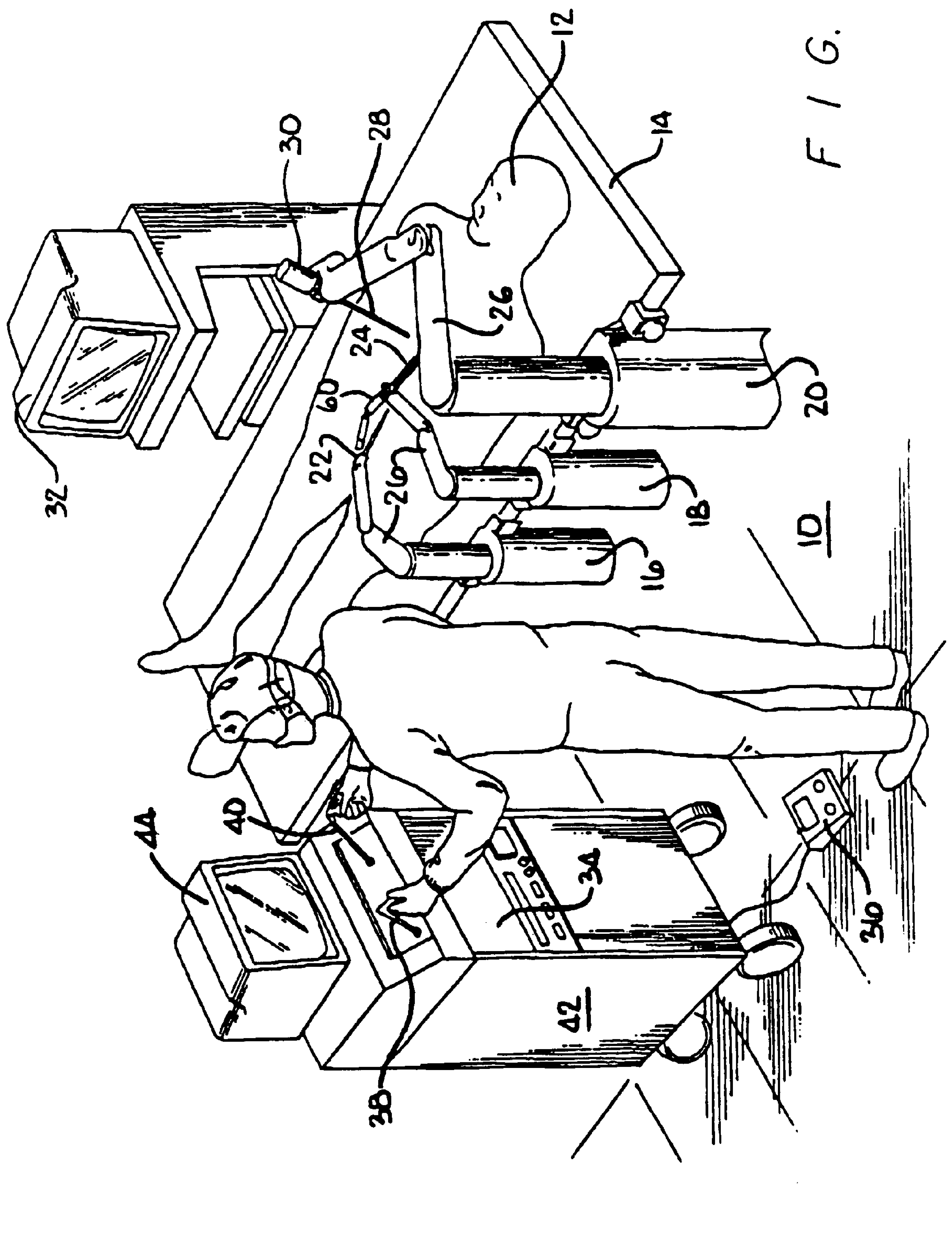

FIG. 1

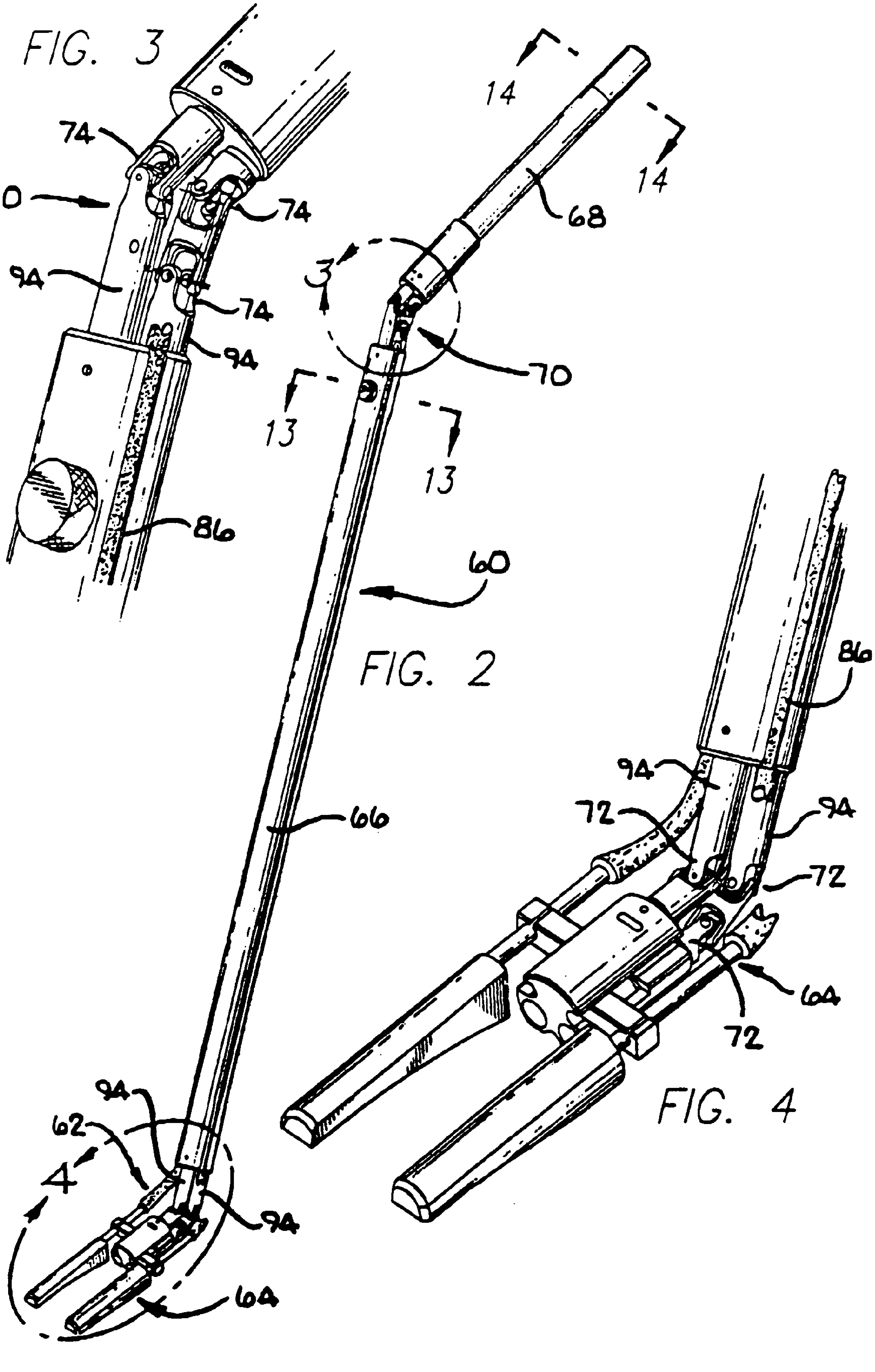
FIG. 3
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FIG. 2
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FIG. 4
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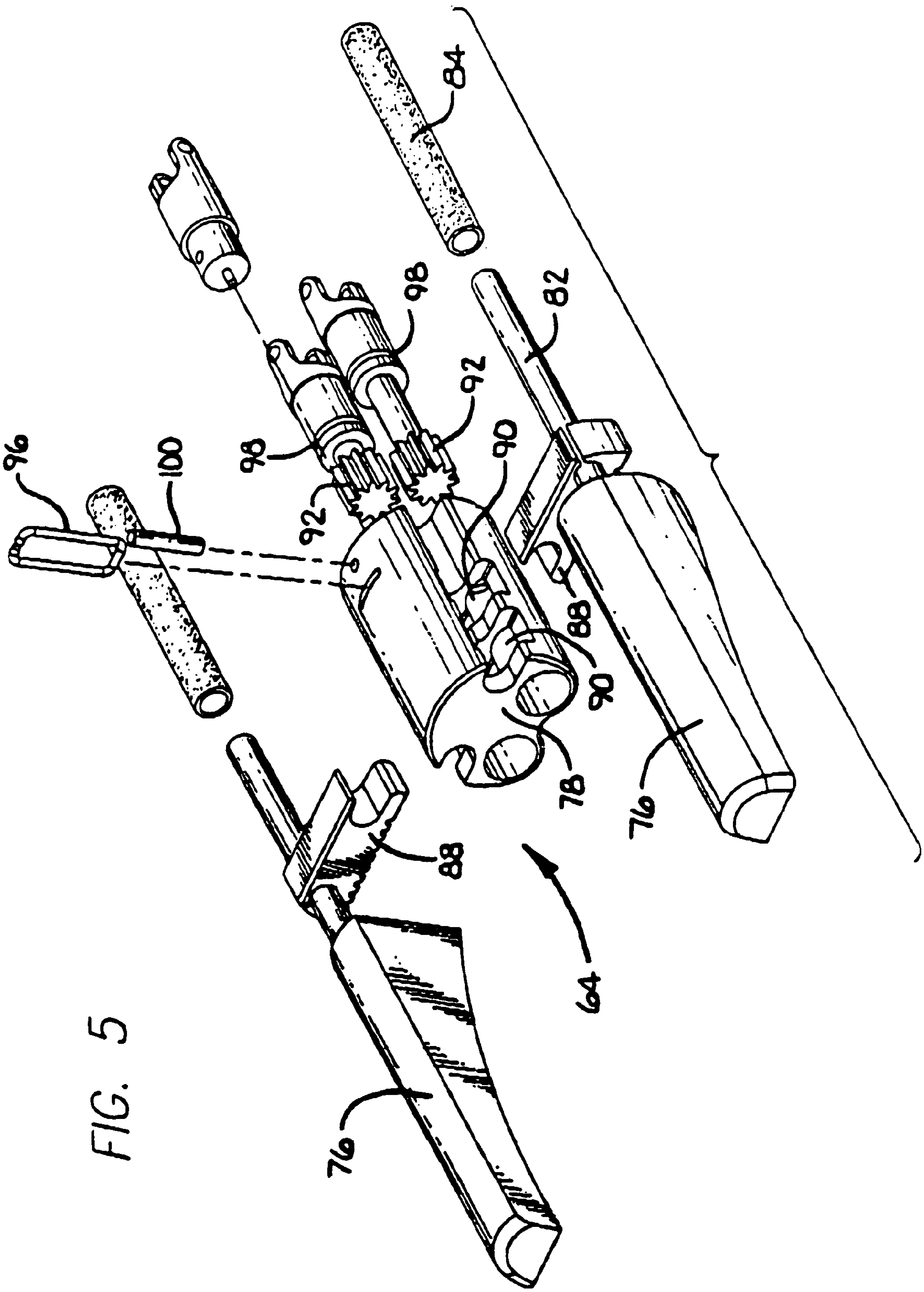

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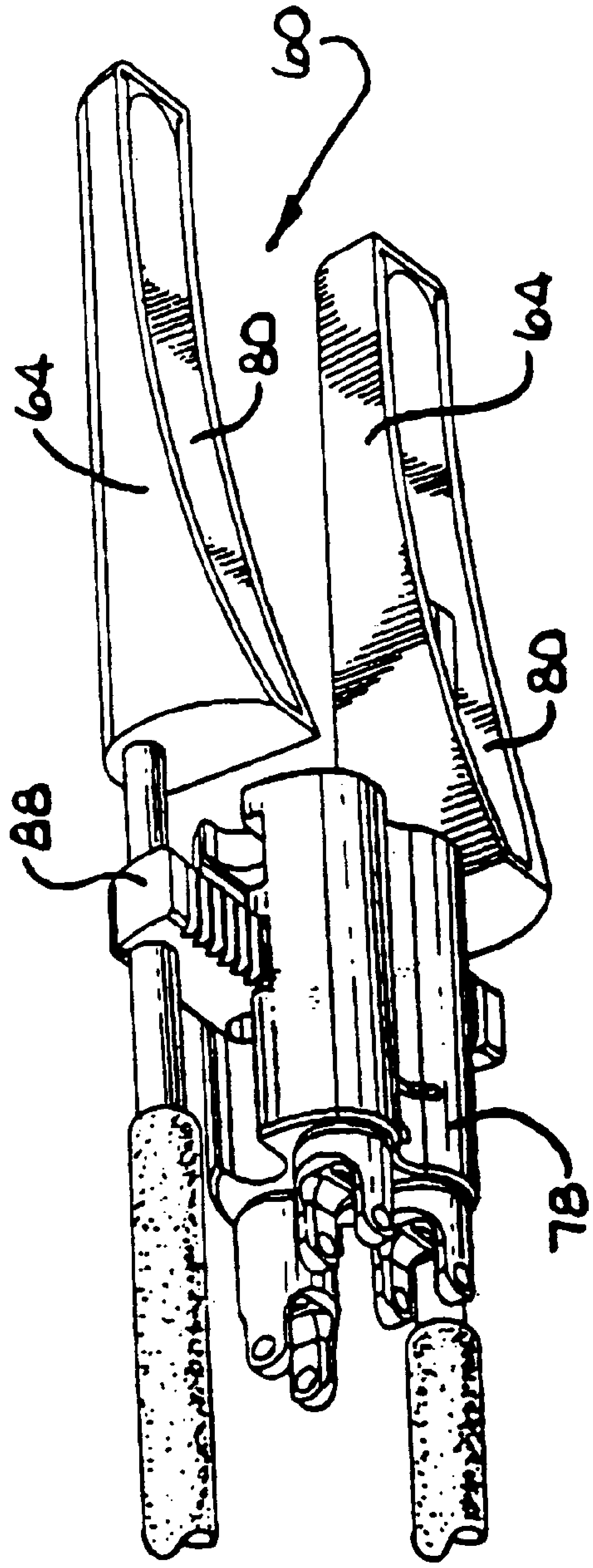
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FIG. 6

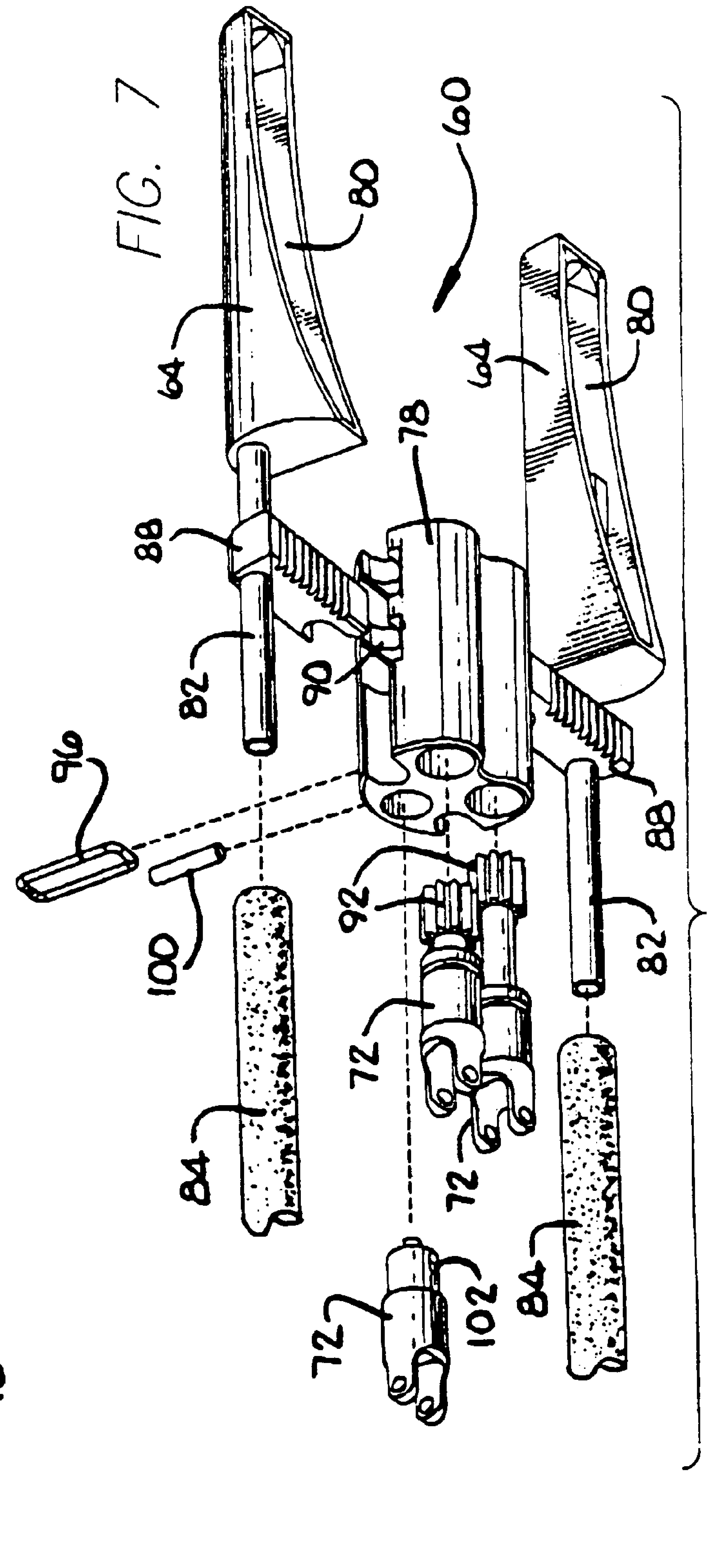
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FIG. 7

FIG. 8

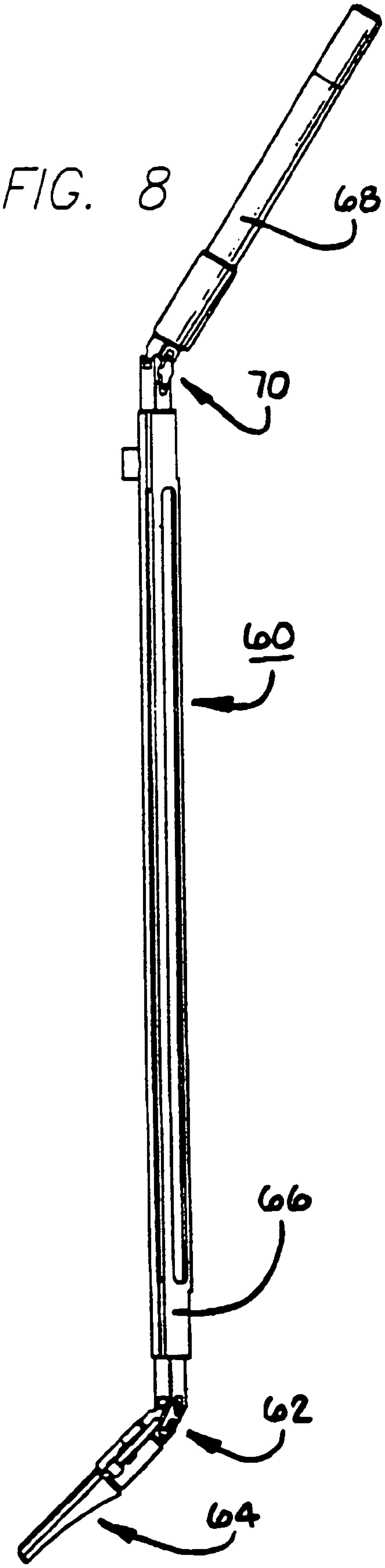
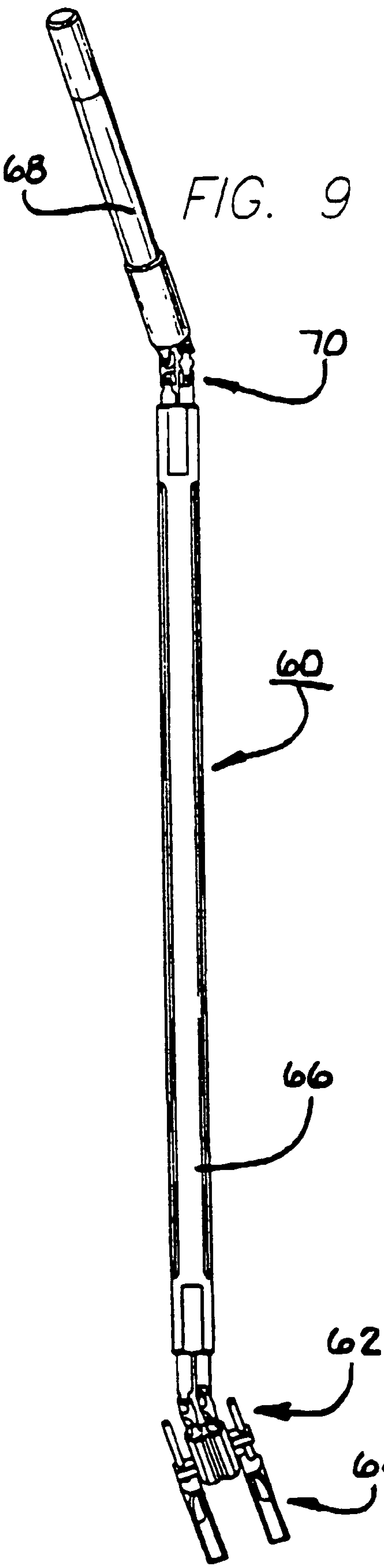


FIG. 9



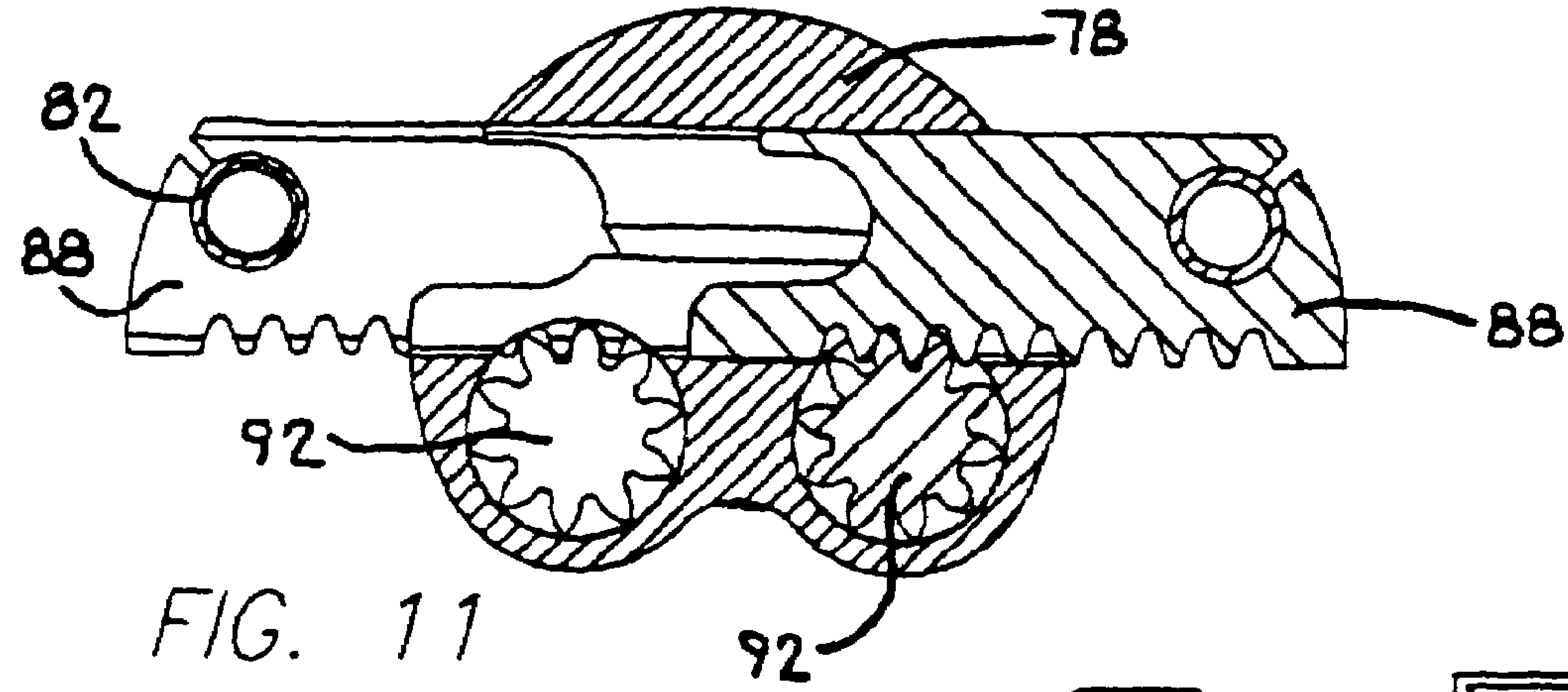
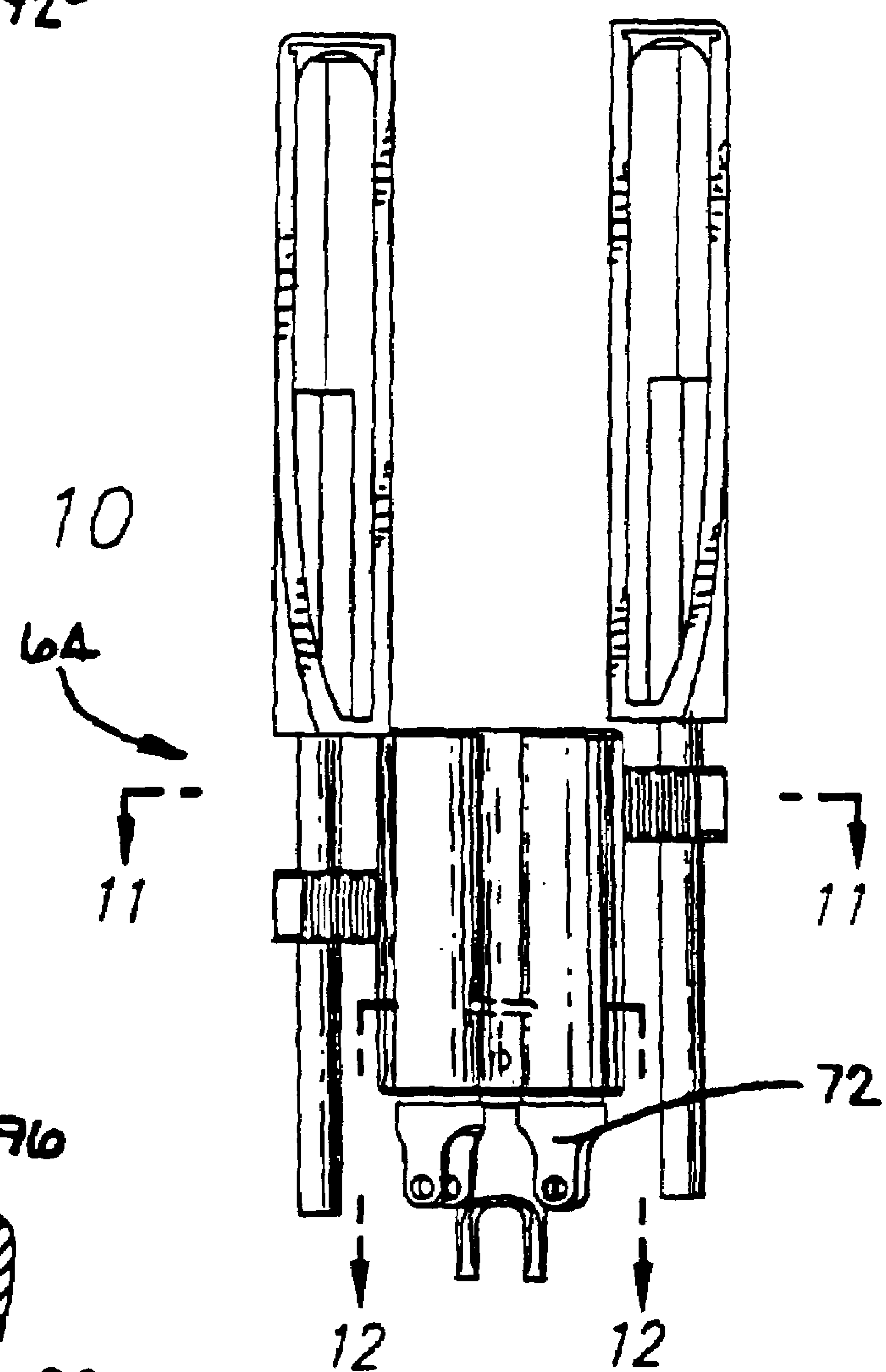


FIG. 11

FIG. 10



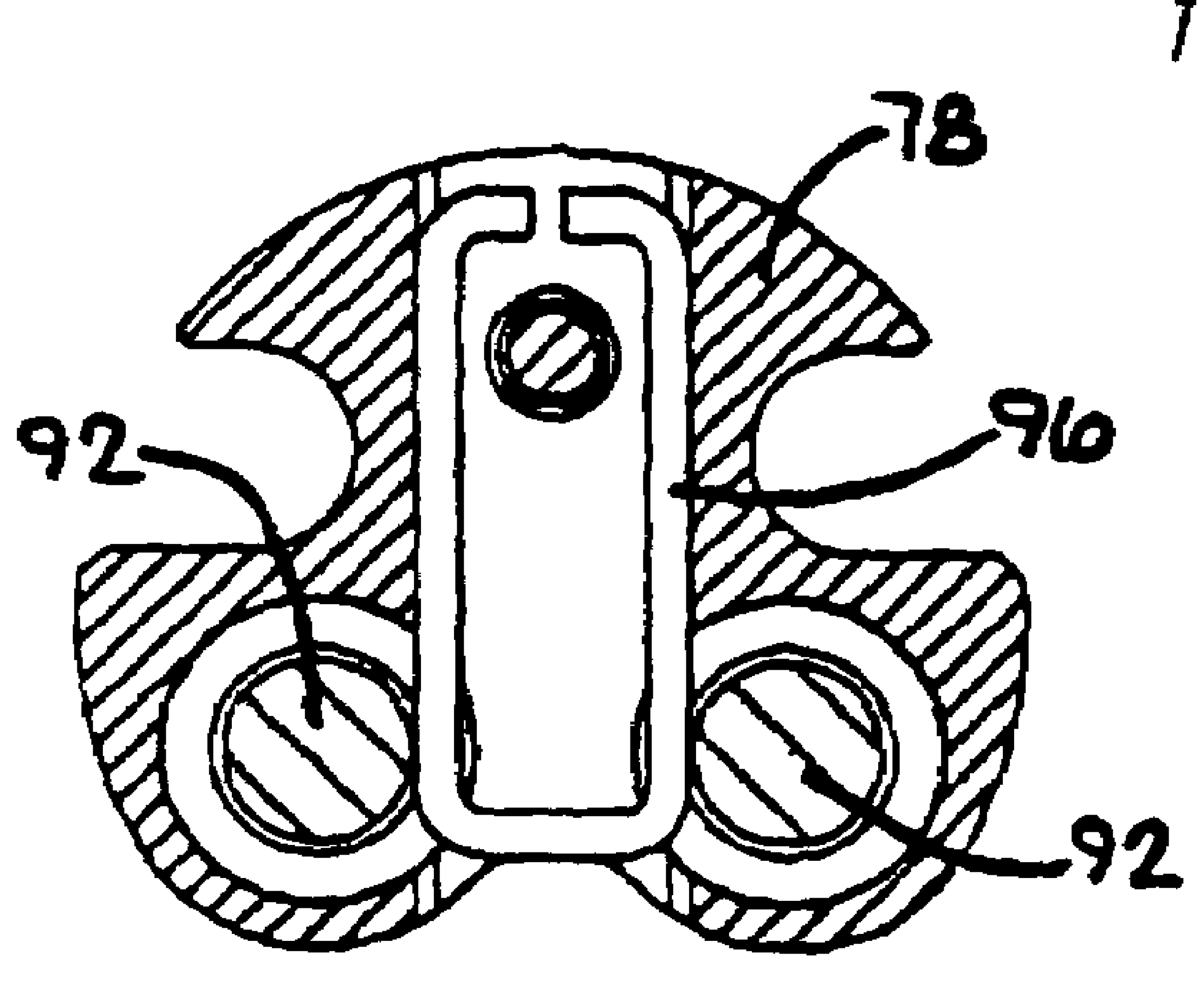


FIG. 12

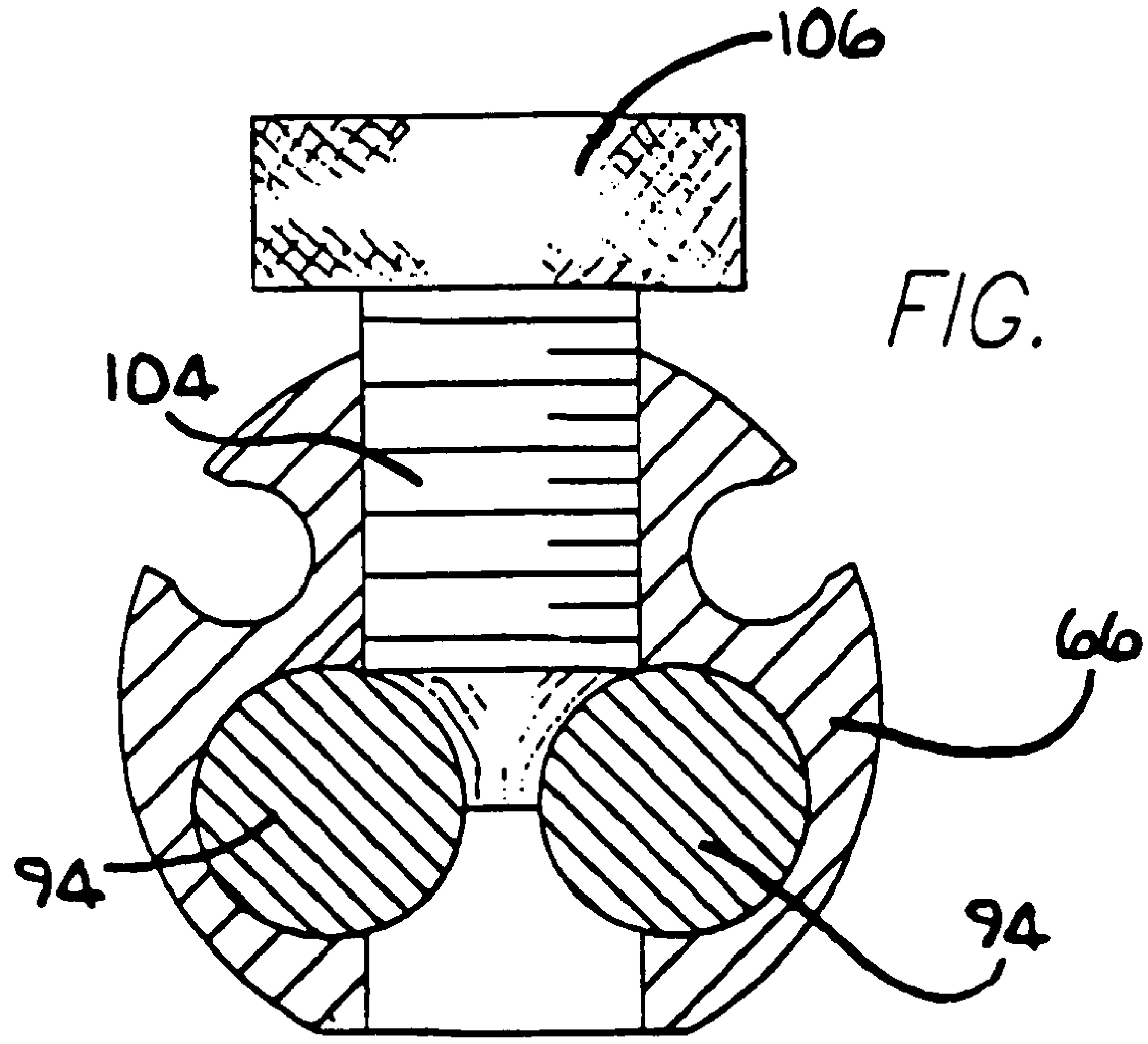


FIG. 13

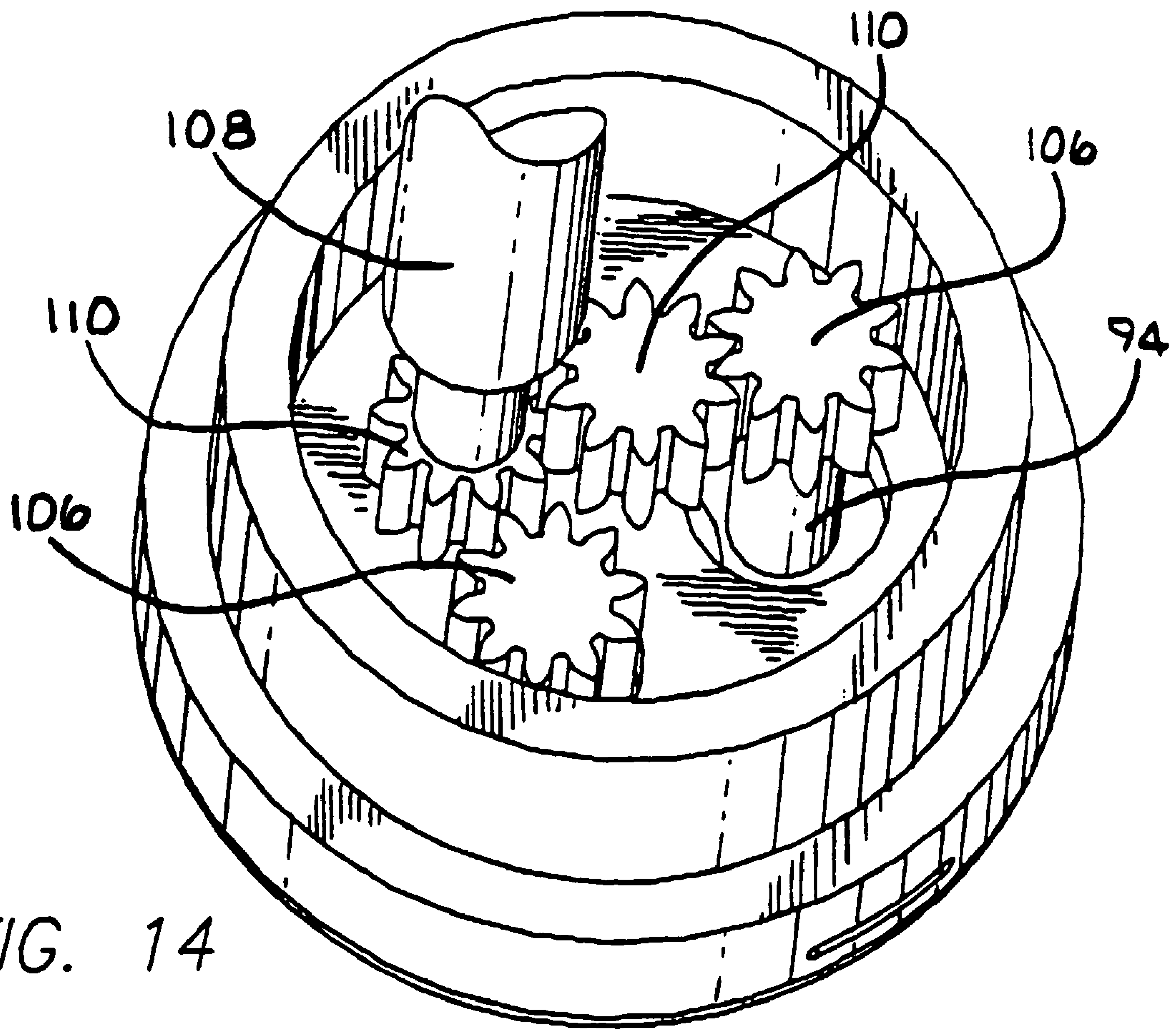


FIG. 14

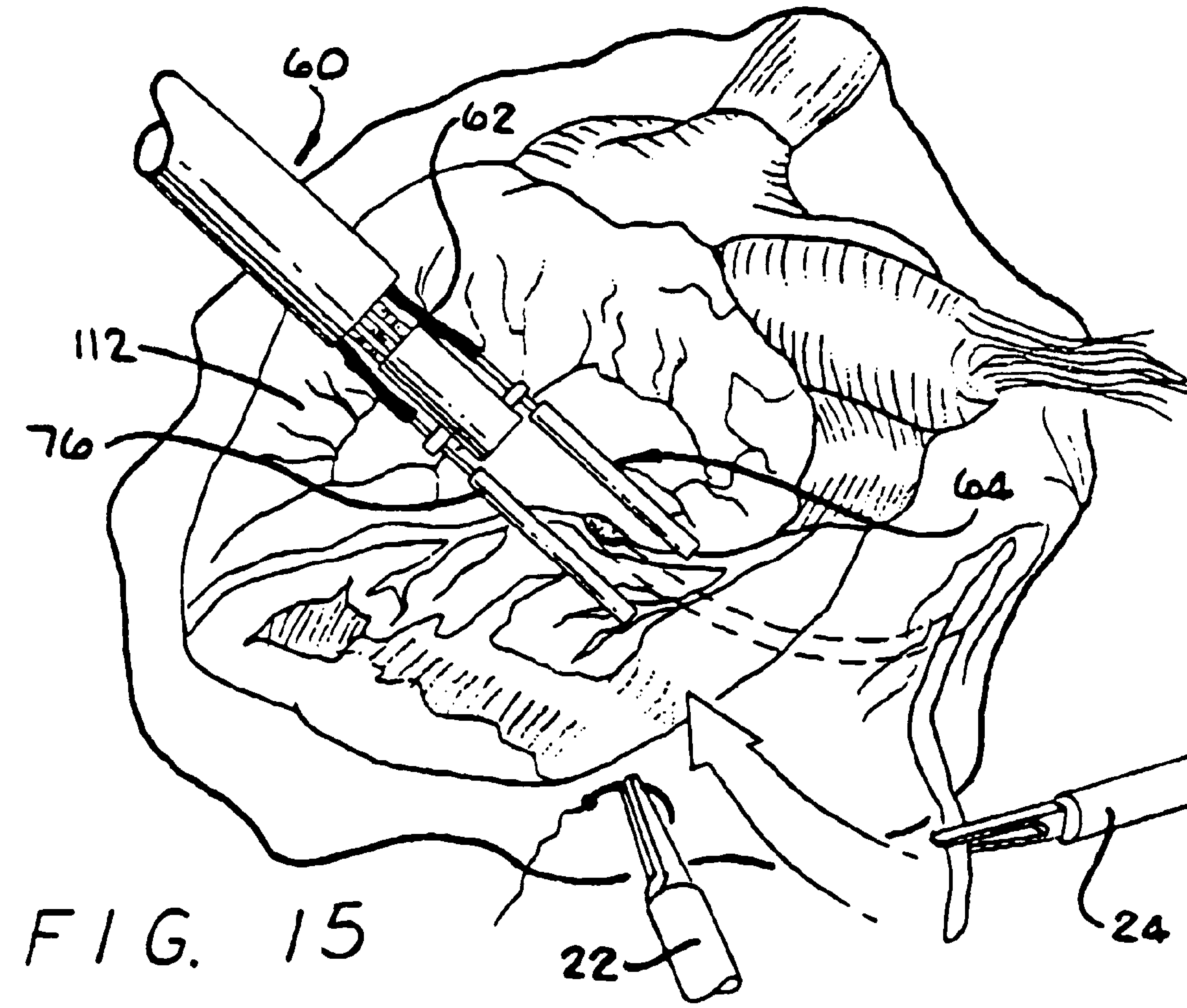


FIG. 15

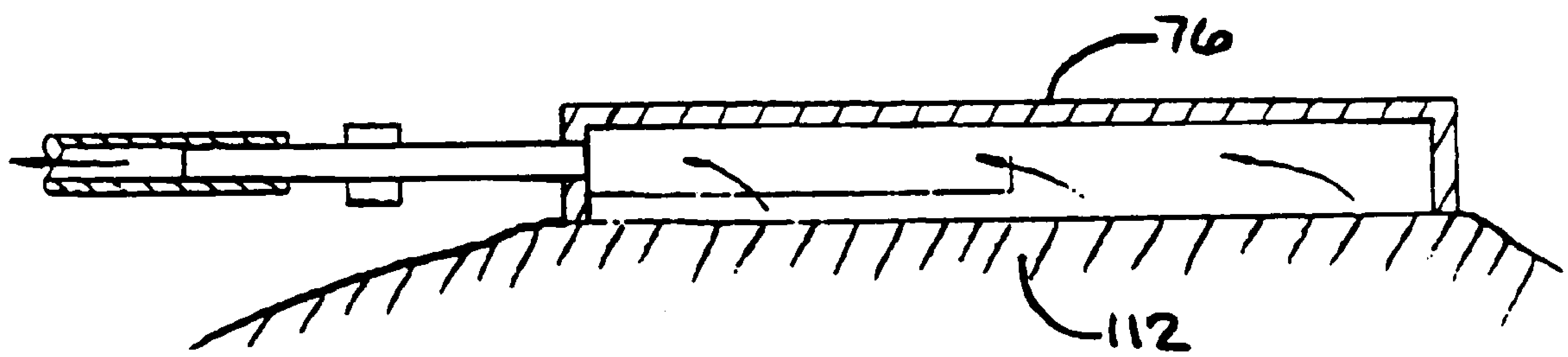


FIG. 16

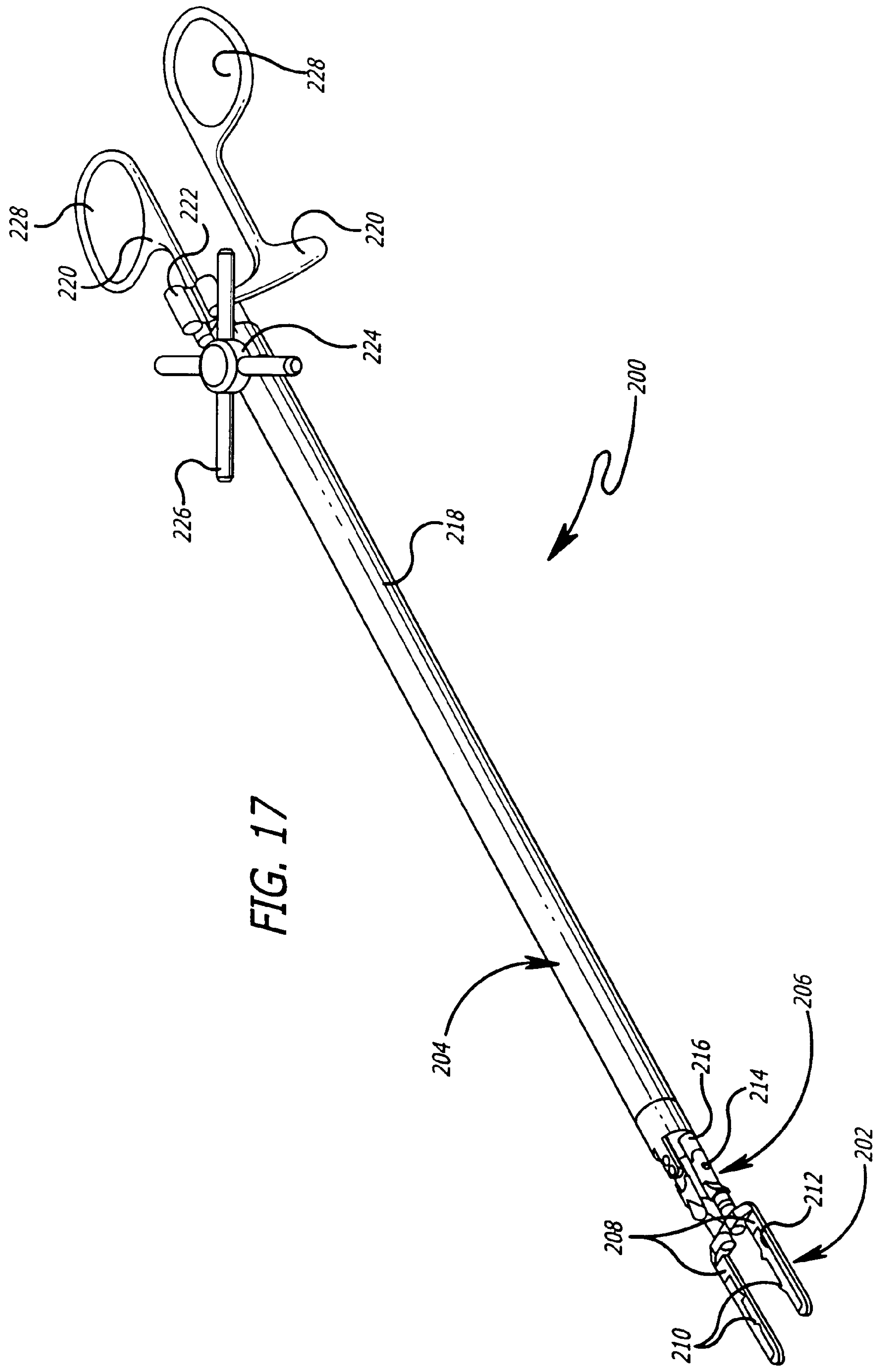

228
228
222
220
220
224
200
226
218
204
216
214
206
202
212
208
210

FIG. 17

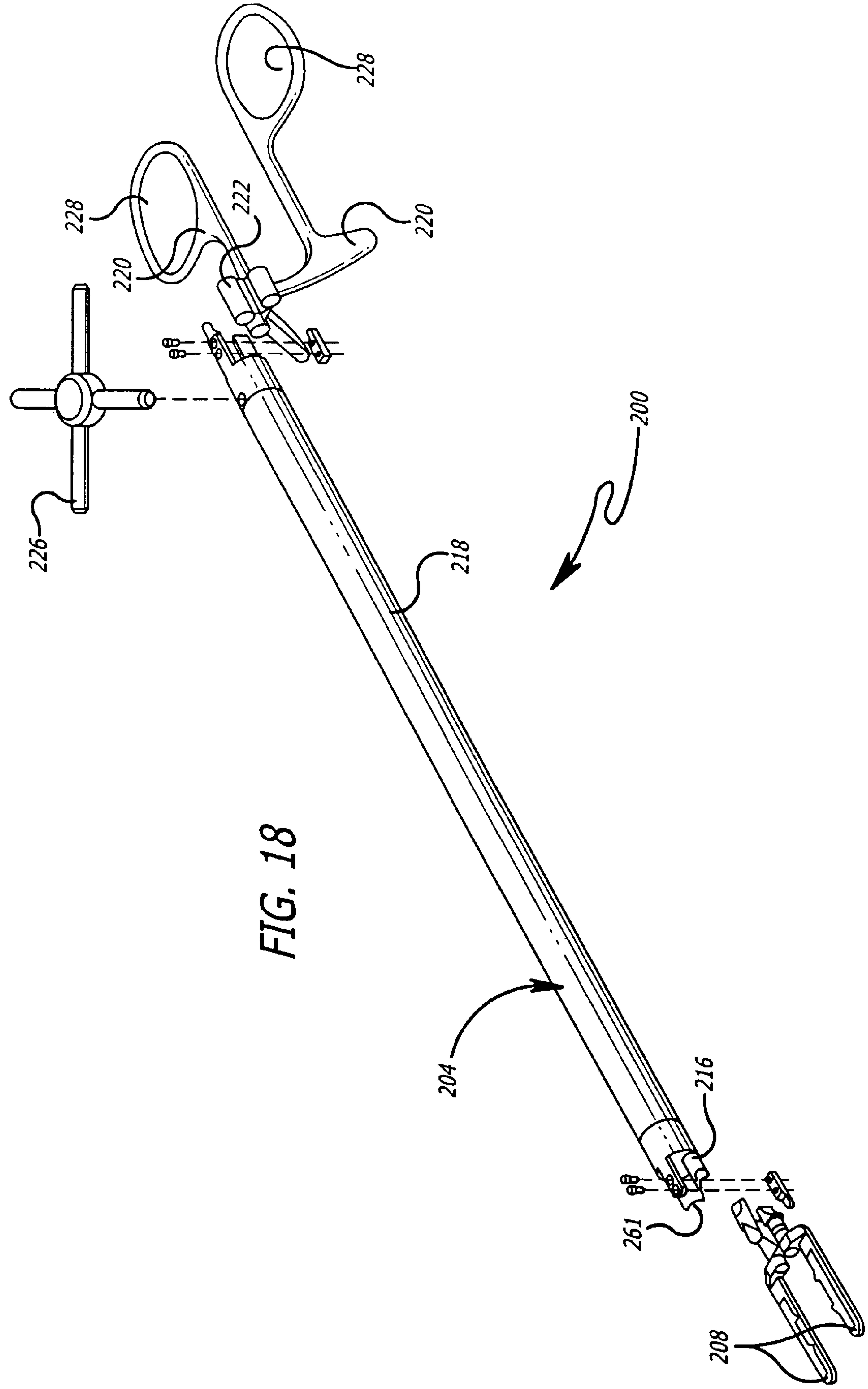


FIG. 18

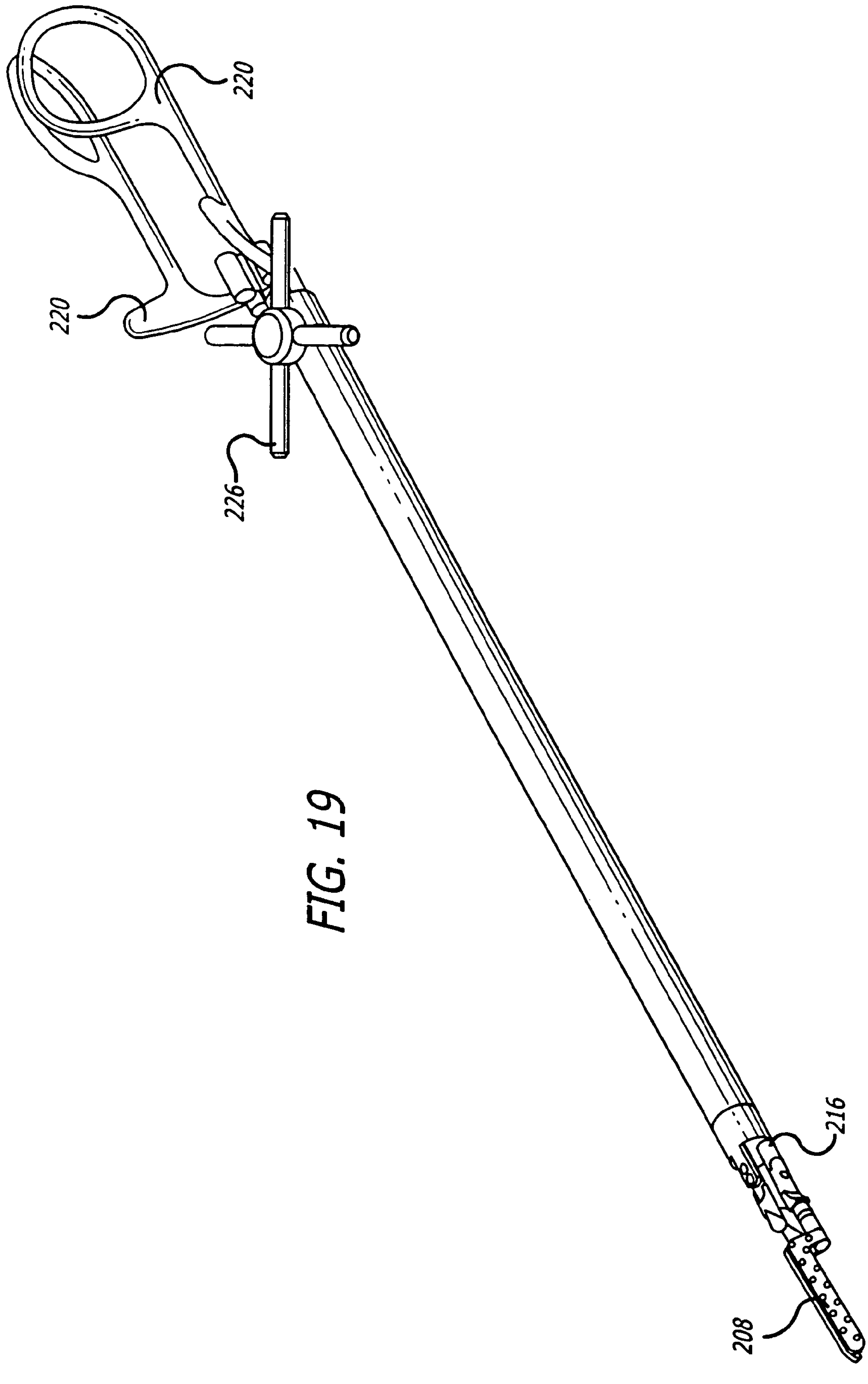


FIG. 19

HEART STABILIZER

CROSS-REFERENCES TO RELATED APPLICATIONS

The present application is a continuation of U.S. Patent application Ser. No. 09/870,331, filed May 29, 2001, now U.S. Pat No. 6,817,972, which was a continuation-in-part of U.S. Patent application Ser. No. 09/411,442, filed Oct. 1, 1999, now U.S. Pat No. 6,936,001, the full disclosures of which are incorporated by reference.

STATEMENT AS TO RIGHTS TO INVENTIONS MADE UNDER FEDERALLY SPONSORED RESEARCH OR DEVELOPMENT

NOT APPLICABLE

REFERENCE TO A "SEQUENCE LISTING," A TABLE, OR A COMPUTER PROGRAM LISTING APPENDIX SUBMITTED ON A COMPACT DISK.

NOT APPLICABLE

BACKGROUND OF THE INVENTION

Field of the Invention

The present invention relates to an articulate heart stabilizer.

Blockage of a coronary artery may deprive the heart of blood and oxygen required to sustain life. The blockage may be removed with medication or by an angioplasty. For severe blockage a coronary artery bypass graft (CABG) is performed to bypass the blocked area of the artery. CAEG procedures are typically performed by splitting the sternum and pulling open the chest cavity to provide access to the heart. An incision is made in the artery adjacent to the blocked area. The internal mammary artery is then severed and attached to the artery at the point of incision. The internal mammary artery bypasses the blocked area of the artery to again provide a full flow of blood to the heart. Splitting the sternum and opening the chest cavity can create a tremendous trauma to the patient. Additionally, the cracked sternum prolongs the recovery period of the patient.

Computer Motion of Goleta, Calif. provides a system under the trademark ZEUS that allows a surgeon to perform a minimally invasive CABG procedure. The procedure is performed with instruments that are inserted through small incisions in the patient's chest. The instruments are controlled by robotic arms. Movement of the robotic arms and actuation of the instrument end effectors are controlled by the surgeon through a pair of handles and a foot pedal that are coupled to an electronic controller. When performing a coronary procedure it is desirable to stabilize the heart. A heart stabilizer can be provided to limit the movement of the heart at the surgical site to reduce the complexity of performing the coronary procedure. To date there has not been developed a heart stabilizer that can be used in a minimally invasive procedure. A minimally invasive heart stabilizer must have enough dexterity to be maneuvered within the chest cavity of the patient.

There have been developed articulate retractors that are used in open-heart surgery. The articulate retractors have a pair of wrist joints that allow pivotally movement of a retractor relative to a handle shaft. The joints are spatially

separated such that manipulation of the retractor is cumbersome and would be impractical for use in a minimally invasive procedure. It would therefore be desirable to provide a heart stabilizer that can be used in a minimally invasive procedure.

BRIEF SUMMARY OF THE INVENTION

One embodiment of the present invention is a heart stabilizer that may include a wrist, which couples an end effector to a first linkage. The end effector and wrist may be inserted through an incision in the chest of a patient to assist in performing a minimally invasive coronary procedure. The end effector may be manually actuated by moving a lever of the stabilizer.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a perspective view of an embodiment of a minimally invasive surgical system of the present invention.

FIG. **2** is a perspective view of an embodiment of a heart stabilizer of the present invention.

FIG. **3** is an enlarged view of an elbow of the heart stabilizer.

FIG. **4** is an enlarged view of an end effector of the heart stabilizer.

FIG. **5** is an exploded view of the end effector.

FIG. **6** is a bottom perspective view of the end effector.

FIG. **7** is a bottom exploded view of the end effector.

FIG. **8** is a side view of the heart stabilizer.

FIG. **9** is a bottom view of the heart stabilizer.

FIG. **10** is a bottom view of the end effector.

FIG. **11** is a sectional view taken at line **11**—**11** of FIG. **10**.

FIG. **12** is a sectional view taken at line **12**—**12** of FIG. **10**.

FIG. **13** is a sectional view taken at line **13**—**13** of 25 FIG. **2**.

FIG. **14** is a sectional view taken at line **14**—**14** FIG. **2**.

FIG. **15** is a top view showing the heart stabilizer fastened to a heart.

FIG. **16** is a side view of the heart stabilizer fastened to the heart.

FIG. **17** is a side perspective view of an alternate embodiment of a heart stabilizer.

FIG. **18** is an exploded view of the heart stabilizer shown in FIG. **17**.

FIG. **19** is a perspective view showing the heart stabilizer of FIG. **17** in a closed position.

DETAILED DESCRIPTION OF THE INVENTION

Referring to the drawings more particularly by reference numbers, FIG. **1** shows a system **10** that can perform minimally invasive surgery. In the preferred embodiment, the system **10** is used to perform a minimally invasive coronary artery bypass graft (MI-CABG) and other anastomostic procedures. Although a MI-CABG procedure is shown and described, it is to be understood that the system may be used for other surgical procedures. For example, the system can be used to suture any pair of vessels. The system **10** can be used to perform a procedure on a patient **12** that is typically lying on an operating table **14**. Mounted to the operating table **14** is a first articulate arm **16**, a second articulate arm **18** and a third articulate arm **20**. The articulate arms **16**, **18** and **20** are preferably mounted to the table **14** so that the arms are at a same reference plane as the patient. Although three articulate arms are shown and described, it is to be understood that the system may have any number of arms.

The first and second articulate arms **16** and **18** each have a surgical instrument **22** and **24**, respectively, coupled to a robotic arm **26**, respectively. The third **25** articulate arm **20** has an endoscope **28** that is held by a robotic arm **26**. The instruments **22** and **24**, and endoscope **28** are inserted through incisions cut into the skin of the patient. The endoscope has a camera **30** that is coupled to a television monitor **32** which displays images of the internal organs of the patient. The first **16**, second **18**, and third **20** articulate arms are coupled to a controller **34** which can control the movement of the arms. The controller **34** is connected to an input device **36** such as a foot pedal that can be operated by a surgeon to move the location of the endoscope **28**. The surgeon can view a different portion of the patient by depressing a corresponding button(s) of the pedal **36**. The controller **34** receives the input signal(s) from the foot pedal **36** and moves the robotic arm **26** and endoscope **28** in accordance with the input commands of the surgeon. The robotic arms **26** may be devices that are sold by the assignee of the present invention, Computer Motion, Inc. of Goleta, Calif., under the trademark AESOP. The system is also described in U.S. Pat. No. 5,657,429 issued to Wang et al., which is hereby incorporated by reference. Although a foot pedal **36** is shown and described, it is to be understood that the system may have other input means such as a hand controller, or a speech recognition interface.

The instruments **22** and **24** of the first **16** and second **18** articulate arms, respectively, are controlled by a pair of master handles **38** and **40** that can be manipulated by the surgeon. The handles **38** and **40**, and arms **16** and **18**, have a master-slave relationship so that movement of the handles **38** and **40** produces a corresponding movement of the surgical instruments. The handles **38** and **40** may be mounted to a portable cabinet **42**. A second television monitor **44** may be placed onto the cabinet **42** and coupled to the endoscope **28** so that the surgeon can readily view the internal organs of the patient. The handles **38** and **40** are also coupled to the controller **34**. The controller **34** receives input signals from the handles **38** and **40**, computes a corresponding movement of the surgical instruments, and provides output signals to move the robotic arms and instruments. The entire system may be a product marketed by Computer Motion under the trademark Zeus. The operation of the system is also described in U.S. Pat. No. 5,762,458 issued to Wang et al. and assigned to Computer Motion, which is hereby incorporated by reference.

The system may also include a heart stabilizer **60** that is used to perform minimally invasive coronary procedures. The stabilizer **60** is typically inserted through an incision of the patient's chest. The stabilizer **60** can be held by a robotic arm or a static structure (not shown).

FIGS. **2**–**14** show an embodiment of a heart stabilizer **60**. Referring to FIGS. **2**, **8** and **9**, the heart stabilizer **60** may comprise a wrist **62** that couples an end effector **64** to a first linkage **66**. The wrist **62** allows the end effector **64** to be moved relative to the first linkage **66**. The first linkage **66** may be coupled to a second linkage **68** by an elbow **70**. The elbow **70** allows the first linkage **66** to be moved relative to the second linkage **68**. The wrist **62** and elbow **70** allow the end effector **64** to be accurately located within the chest cavity of a patient. Each linkage **66** and **68** may be a cannula with an inner longitudinal channel.

As shown in FIGS. **3** and **4** the elbow **70** and wrist **62** may have a plurality of universal joints **72** and **74**, respectively, that provide three degrees of freedom. At least two universal joints **72** of the wrist **62** may pivot about the same plane to minimize the relative movement of one joint pivot point relative to another joint pivot point. Relative pivot point movement can increase the complexity of positioning the end effector **64**. Likewise, two or more universal joints **74** of the elbow **70** can pivot about the same plane.

Referring to FIGS. **5**, **6**, **7**, **10**, **11** and **12**, the end effector **64** may have a pair of paddles **76** that can move relative to a gear housing **78**. Each paddle **76** may have an opening **80** that is in fluid communication with a rigid tube **82**. Each rigid tube **82** may be connected to a flexible tube **84**. The flexible tubes **84** may be connected to a source of vacuum (not shown) that can create a vacuum pressure at the openings **80**. The flexible tubes **84** can be routed along channels **86** of the first linkage **66**, as shown in FIGS. **2** and **4**, to minimize the profile of the stabilizer **60**. Although suction paddles are shown and described, it is to be understood that the heart stabilizer **60** may be used without a suction system. Each rigid tube **84** may be connected to a gear rack **88**. Each gear rack **88** can move within corresponding channels **90** of the gear housing **78**. The gear racks **90** may be coupled to corresponding pinion gears **92** attached to two of the universal joints **72** of the wrist **62**.

The universal joints **72** may be connected to a pair of drive shafts **94** that extend through the first linkage **66** as shown in FIGS. **2**, **3** and **4**. Rotation of the drive shafts **94** will rotate the pinion gears **92** and translate the corresponding gear racks **88** and paddles **76** in an inward or outward direction. The movement of the paddles **76** occurs without disturbing the relative position of the end effector **64** to the first linkage **66**. As shown in FIGS. **5**, **7** and **12**, the end effector **64** may include a spring clip **96** that is inserted into corresponding annular grooves **98** of the pinion gears **92** and captures the gears **92** within the gear housing **78**. The end effector **64** may also have a pin **100** that is inserted into a corresponding aperture **102** of the other universal joint **72** to capture the joint **72** within the gear housing **78**.

As shown in FIG. **13**, the heart stabilizer **60** may include a locking pin **104** that can be pressed into the drive shafts **94** to prevent rotation of the shafts **94**. Impeding shaft rotation locks the position of the wrist **62**, elbow **70** and paddles **76**. A surgeon may lock and unlock the wrist **62**, elbow **70** and paddles **76** by rotating a head **106** of the pin **104**.

As shown in FIG. **14**, each drive shaft **94** may have a pinion gear **106** that is coupled to an output shaft **108** of a motor (not shown) by a pair of coupling gears **110**. Rotation of the output shaft **108** rotates the drive shafts and moves the paddles **76**. The motor is preferably reversible so that the paddles **76** can be moved inward or outward. The motor may be connected to the controller **34** and foot pedal **36** shown in FIG. **1**. The surgeon can move the paddles **76** inward or outward by depressing a corresponding switch(es) of the foot pedal **36**. Alternatively, the motor can be actuated through voice recognition.

As shown in FIGS. **15** and **16**, the end effector **64** and wrist **62** can be inserted into the patient's chest cavity adjacent to the heart **112**. The surgeon can view the location of the end effector **64** relative to the heart **112** on the monitor **32** shown in FIG. **1**. The surgeon can grasp the second linkage **66** and move the stabilizer **60** until the end effector **64** is correctly located on the heart **112**. The drive motor can then activated to move the paddles **76** to the desired location. The surgeon may then turn the locking pin to secure the position of the stabilizer **60** relative to the patient.

As shown in FIG. **16**, the vacuum source maybe activated to pull the heart **112** into the paddles **76**. The stabilizer **60** will then prevent movement of the adjoining area of the heart while the surgeon performs a coronary procedure with the surgical instruments **22** and **24**. After the procedure is completed, the stabilizer **60** can be removed by terminating the vacuum and pulling the end effector **64** out of the chest cavity.

FIGS. **17** and **18** show another embodiment of a heart stabilizer **200** that can be manually operated. The heart stabilizer **200** includes an end effector **202** that is coupled to a first linkage **204** by a wrist **206**. The end effector **202** may include a pair of paddles **208**. The paddles **208** can be placed onto a beating heart to stabilize the organ. The paddles **208** may have cleats **210** that can anchor sutures used to perform a medical procedure. The sutures can be attached to open wire ends **212** of the cleats **210** during the procedure. For example, sutures are typically used to restrict blood flow during a coronary by-pass procedure. The restricting sutures can be anchored by the cleats **210** and paddles **208** of the stabilizer **200**.

The wrist **206** may include an arrangement of universal joints **214** that allow multi-axis rotation of the end effector relative to the first linkage **204**. A single universal joint directly couples the end effector **202** to the first linkage **204** to serve as a multi-axis pivot. A sequence of two universal joints **214** couples the shaft of each paddle **208** to its drive shaft **216** that extends through a tube **218** of the linkage **204**. An identical sequence of two universal joints (or double universal joint linkage) couples each of the two drive shafts **216** to its respective manually actuated levers **220**. The levers **220** can rotate relative to a bracket **222** that is attached to the tube **218**. A single universal joint couples the bracket **222** to the first inkage **204**, serving as a multi-axis pivot for the bracket **222**. Rotation of the levers **220** spins the drive shafts **216**, and rotates the paddles **208** between an open position and a closed position. When fully open the paddles **208** contact mechanical stops which prevents further rotation of the levers **220**. At this point the levers **220** serve as handle which the operator may use to reorient the bracket **222** assembly relative to the first linkage **204**. When such rotation about the bracket **222** pivot universal joint takes place the double universal joint linkages to each driveshaft **216** cause the driveshafts to translate axially relative to the first linkage **204**. The double universal joint linkages coupling the driveshafts **216** to the paddle shafts **208** communicate this motion to the end effector **202**. The result is that the end effector **202** motion mimics that of the bracket **222**. The stabilizer **200** includes a locking pits **224** with a knob **226** that can be rotated by the user to lock and unlock the drive shafts **216** and thereby fix the position of the end effector **202** and paddles **208**. The levers **220** may have openings **228** designed to receive fingers of a user.

In operation, the user rotates the levers **220** to move the paddles **208** into the closed position shown in FIG. **19**. The knob **226** is preferably rotated to lock the position of the paddles **208**. The stabilizer **200** can then be inserted through a cannula and into an internal cavity of a patient. The knob **226** can be manipulated to unlock the drive shafts **216** so that the levers **220** can be rotated to move the paddles **208** into an open position. Further manipulation of the levers **220** reorients the end effector to the desired position on the heart at which point the knob **226** can be rotated to lock the position of the paddles **208**. The entire instrument is then locked in place (relative to the patient) using a static or robotic support arm (not shown). Sutures can be anchored by attachment to the cleats **210** of the paddles **208**. When the procedure is completed, the paddles **208** can be moved back to the closed position and the stabilizer **200** can be pulled out of the patient.

As with the previous embodiment, this device may use paddles which employ suction to enhance gripping of the heart tissue. Through suitable modification of the paddles, both embodiments may be used to implement doubly articulating grasping instruments, scissors, clip appliers and other manual instruments. While primarily intended for endoscopic use, all of the instruments described herein are equally suitable for conventional or open surgical procedures. By directly actuating the axial and rotary motions of the driveshafts **216** and eliminating the bracket and levers, robotic versions of all these instrument types can be constructed.

While certain exemplary embodiments have been described and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive on the broad invention, and that this invention not be limited to the specific constructions and arrangements shown and described, since various other modifications may occur to those ordinarily skilled in the art. For example, although the medical devices shown in FIGS. **2**–**14** and **17**–**19** has been shown and described as a heart stabilizer, it is to be understood that the devices can be used as a retractor. The paddles **76** and **208** can be used, or modified to be used, as retractor jaws.

What is claimed is:

1. A surgical instrument, comprising:

a linkage;

a first shaft extending through the linkage;

a second shaft extending through the linkage; and

an end effector;

wherein the end effector comprises a first paddle and a second paddle, the first and second paddles being substantially parallel;

wherein the end effector is coupled to the linkage via a first universal joint;

wherein the first paddle is coupled to the first shaft via a second universal joint;

wherein the second paddle is coupled to the second shaft via a third universal joint;

wherein translation of the first shaft, translation of the second shaft, or translation of both the first and the second shaft moves the end effector;

wherein rotation of the first shaft moves the first paddle; and

wherein rotation of the second shaft moves the second paddle.

2. The surgical instrument of claim **1**, wherein the end effector comprises a heart stabilizer.

3. The surgical instrument of claim **1** further comprising an opening in at least one of the paddles, the opening being configured to provide suction.

4. The surgical instrument of claim **1**, wherein the end effector comprises a retractor.

5. The surgical instrument of claim **1**, wherein the rotation of the first shaft is motor driven.

6. The surgical instrument of claim **5**, wherein the motor is voice activated.

7. The surgical instrument of claim **1**, wherein the rotation of the first shaft is manually actuated.

8. The surgical instrument of claim **1**, wherein the rotation of the first shaft turns a pinion gear engaged with a rack.

9. The surgical instrument of claim **1** further comprising a locking pin that locks a position of the end effector.

* * * * *